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TEMPORAL VARIATION IN GROUNDWATER QUALITY OF AMBALA CITY AND AMBALA CANTONMENT AREA, HARYANA, INDIA

RITU SARSOHA & MADHURI S. RISHI

Department of Environment Studies Panjab University, Chandigarh, India

ABSTRACT

Groundwater is an essential commodity for the survival of human race. Urbanization coupled with population and industrialization has caused incomplete interaction between various flow compartments of the aquifer. In the present study, physico-chemical characteristics of groundwater of Ambala city and Ambala cantonment area were assessed for its suitability for drinking purpose. Samples were collected from deep aquifer based tube wells and shallow aquifer based hand pumps from several parts of Ambala City and Ambala Cantonment. To determine the ground water quality, the water samples were analyzed for sixteen physicochemical parameters from forty five different location for pH, electrical conductivity (EC), total dissolved solids (TDS), calcium, magnesium, total hardness (TH), sodium, potassium, carbonate, bicarbonate, chloride, fluoride, nitrate, sulphate, phosphate and total alkalinity (TA) concentrations during pre and post monsoon season. Bureau of Indian Standard (BIS, 2012) and World Health Organization (WHO, 2003) standards were used to compare the results obtained. High pH at various locations indicated that groundwater of the study area is alkaline in nature. Excluding some of the sampling sites, the overall results showed that the water in the study area is potable.

KEYWORDS: Urbanization, Alkalinity, Physico-chemical Parameters, Water Quality

INTRODUCTION

Earth is known as “Blue Planet” as 74% of the earth’s surface is covered with water, yet when it comes to availability of freshwater for human use it becomes a scarce resource. Water is the most widely distributed substance on the Earth’s surface and occupies a special place than any other natural resources, though its distribution is uneven and hence, the shortage and the related crisis. Groundwater, a precious gift of nature, is vital for the very existence of life and accounts for about 88 % of safe drinking water in rural areas of India, where population is widely dispersed and the infrastructure needed for treatment and transportation of surface water does not exist. India has 15% of the world’s population but only 4% of the world’s water supply is available here (Singh, 2003). Preserving the quality and the availability of the fresh water resources are the most pressing of the many environmental challenges on the national horizon. The question of sustainability is not only a matter of adequate water availability but also maintaining its good quality. It has been recently estimated that by 2017, India will be ‘water stressed’ and per capita availability will decline to 1600 cubic meters (Gupta and Deshpande, 2004).The direct impact of intensive agriculture is the increased pressure on water bodies by way of their pollution by the chemicals, insecticides and pesticides, which leach into under lying aquifers (Patel et al., 2004). It has been established that once pollutant enters in subsurface environment, it remain concealed for many years getting dispersed over wide areas of aquifers and thus, rendering the groundwater supplies unsuitable for human consumption and other usage (Datta et al., 2000).According to World Health Organization, safe drinking water is the basic necessity for the development, health and wellbeing of mankind. The problems related to water quality have been

reported from various parts of state of Haryana; for instance, the water quality in the villages of Jind district contains fluoride content above permissible limits (Meenakshi et al., 2004).

Increased urbanization, rapid industrialization and population explosion drastically changed the hydrological cycle of the Ambala City and Ambala Cantonment. Therefore Ambala City and Ambala Cantonment in Haryana was chosen as target area to assess the quality of groundwater and workout the relationship between the various parameters, temporal changes (in pre-monsoon and post monsoon seasons) and find the type of water existing in the study area.

Description of the Study Area

Ambala district of Haryana lies between 30° 10'31° 35' N latitudes and 76° 30' 77° 10' E longitudes (Figure 1).Total geographical area of the district is around 1574 sq.km. The district area is mainly drained by three non-perennial rivers namely, Markanda, Dangri (Tangri) and Ghaghar & their tributaries. The area under investigation forms a part of Indo-Gangetic alluvial plain of Quaternary age. Alluvial thickness in the district is large and the basement rock is estimated to be encountered at 3000 m depth bmsl and thickness of alluvium thins down towards southwest direction. In south west and western parts of the district the sediments are finer grained in nature, and constituted of fine to medium grained sands, clays, silts and kankars with occasional gravel. The administration has constructed tube wells of varying depths ranging from 175m to 400m for drinking water supply to Ambala city and Ambala Cantonment. The total number of registered factories under section 2m (i) in the study area was 10,513. The main type of industries found in the study area include scientific equipment manufacturing companies, metal industries, pharmaceuticals factories, rubber and plastic products industries, food products and beverages industries, publishing, printing, electrical machinery and apparatus, mining industry, leather industry, chemical industry. (Statistical Abstract, Haryana, 2011).

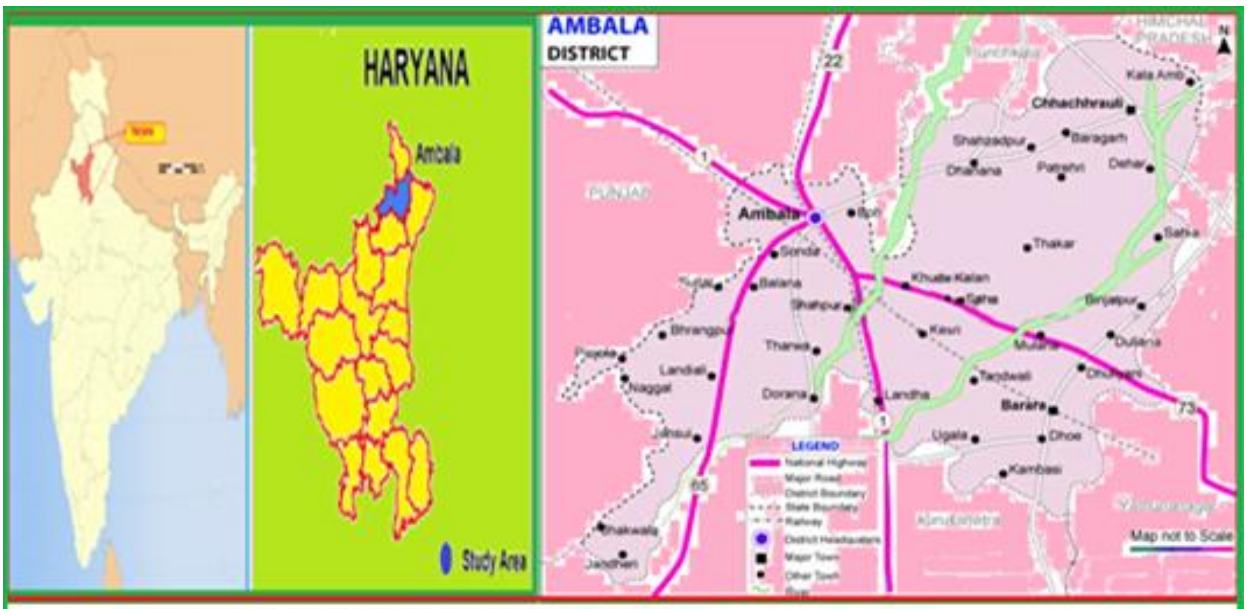

Fig. 1. Location Map of the Study Area

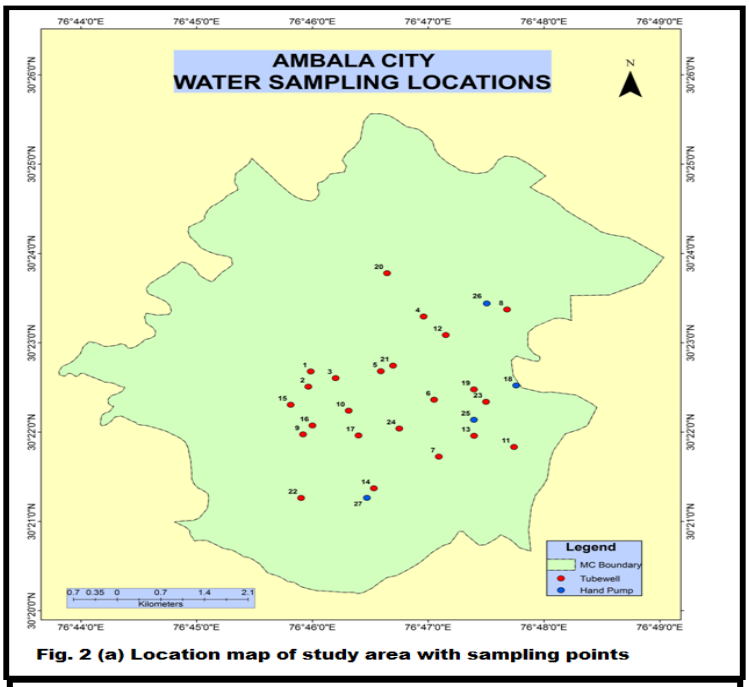

Fig. 2 (a) Location map of study area with sampling points

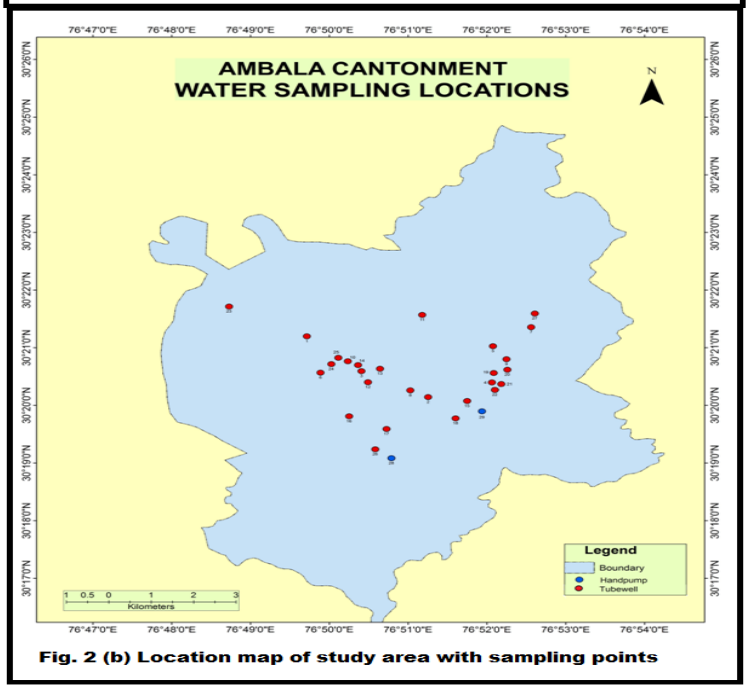

Fig. 2 (b) Location map of study area with sampling points

MATERIALS AND METHODS

A total of 45 groundwater samples from different handpumps and tubewells were collected from the different locations of the study area in the month of May (Pre monsoon) and October (post monsoon) in the year 2011and were subjected to chemical analysis (Figure 2. a&b). The samples were stored in clean plastic bottles with screw caps. Prior to sample collection, all the plastic bottles were thoroughly washed and sun-dried and before sample collection the plastic bottles were rinsed twice with the same collected water samples. The bottles were then labeled and the coordinates of the sampling sites were duly noted. Parameters like Temperature, pH, EC and TDS were analyzed on the spot using potable water and soil analysis kit.

Laboratory Investigation

The water samples were analyzed at the Geochemical Laboratory of Center for Advanced Studies in Geology at Panjab University, Chandigarh. Parameters such as total calcium (Ca^{2+}), magnesium (Mg^{2+}), total hardness (TH), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), fluoride (F^{-}) and sulphate (SO_4^{2-}), nitrate(NO_3^{2-}), and phosphate(PO_4^{3-}) were analyzed following APHA (2003). All the reagents used in the present study were of AR grade and distilled water was used for experimental purpose. For sampling and analysis all the precautions were taken as prescribed by APHA, AWWA, WPCF (2003). The detailed results are presented in Table 1.

Hydrogen Ion Activity (pH)

pH is a term used to express the acidic or alkaline condition of a substance. During pre monsoon, pH value in analyzed water samples varied from 7.0 to 9.8 and the highest value 9.8 was observed near church, Ambala city. During post monsoon the highest value 7.3 was observed at Cloth market, Ambala city. A low value of pH has been observed during post monsoon period ranging between 6.3 to 7.3. The result showed that groundwater of the study area is slightly alkaline in nature. Approximate 2.2% of the samples were above the desirable limit during pre monsoon. All of the samples were found within desirable limit during post- monsoon.

Electrical Conductivity (EC)

Electrical conductivity is the measure of the amount of electrical current a material can carry. The permissible limit for electrical conductivity (EC) is 300 µS /cm. EC of the collected samples ranged from 192 to 3724 µS /cm for pre monsoon (figure 3. a), maximum at Police line, Ambala city while in post monsoon (figure 3.b) the range varied from 786 to 1905 µS /cm, which is lower than pre monsoon). Slight increase or decrease in EC values may be due to concentration and rainfed dilution during pre and post monsoon (Kupwade and Langade, 2013). During pre monsoon 97.7% of the samples were found above desirable limit while all of the samples were found above desirable limit during post- monsoon. During post monsoon the highest value (1905 µS /cm) was observed at new grain market, Ambala cantonment.

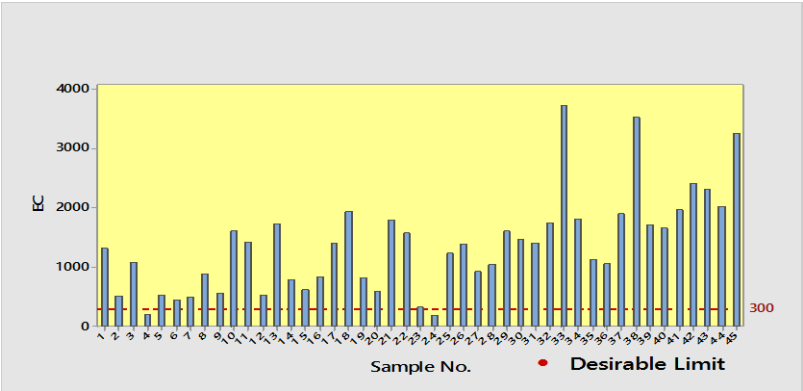

Figure 3: (a) Distribution of EC (Pre- Monsoon)

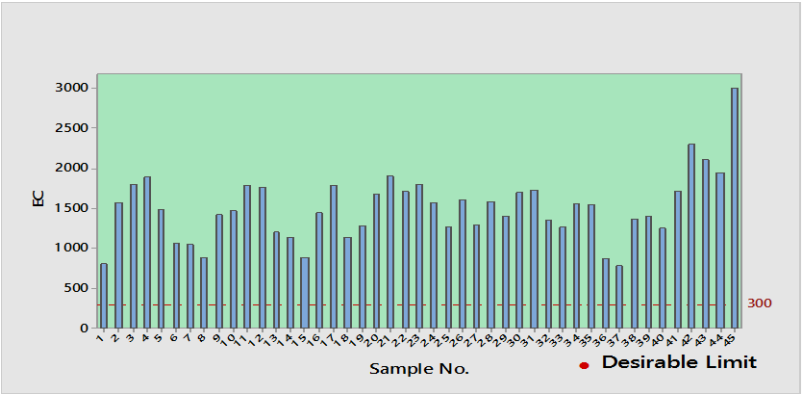

Figure 3: (b) Distribution of EC (Post- Monsoon)

Table 1: Summary Statistics of Chemical Constituents of Groundwater in Ambala City and Ambala Cantonment Area with % of Sample beyond Desirable Limit (DL) as per the BIS Drinking Water Standard

Parameters	BIS Standards (2012)		WHO Limit	Range of samples		Samples above Acceptable limit of BIS (Pre- Monsoon)	Samples above Acceptable limit of BIS (Post- Monsoon)
	Desirable Limit	Maximum Limit		Pre- Monsoon	Post- Monsoon		
pH	6.5-8.5	6.5-9.2	6.5-9.2	7.0-9.8	6.3- 7.3	2.2%	Nil
EC	300	-	-	192-3724	786- 1905	97.7%	100%
TDS	500	2000	500	121-1556	509- 1338	62.2%	53%
TH	300	600	100	28-560	134- 542	13.3%	17.7%
Na^+	-	-	-	3.4-245.49	83.7-396.9	-	-
K^+	-	-	-	0.8- 10.8	0.4- 18.7	-	-
Ca^{2+}	75	200	75	4.2- 227.1	7.6- 338.6	46.6 %	46.6%
Mg^{2+}	30	100	150	1.7- 129.7	0- 114	53.3%	57.7%
CO_3^{2-}	75	200	75	0.0- 175	0.0- 75	Nil	Nil
HCO_3^{2-}	30	-	150	0.0- 1000	35-335	100%	100%
Cl^-	250	1000	200	21.3- 582	49- 788	26%	44.4%
F^-	1.0	1.5	1	0.39-0.65	0.39- 0.48	Nil	Nil
SO_4^{2-}	200	400	200	107- 284	100- 300	Nil	Nil
NO_3^-	45	-	-	0-9.6	0-6.3	Nil	Nil
PO_4^{3-}	-	-	-	0-0.7	0-1.2	Nil	Nil
TA	200	600	200-600	62- 728	76- 918	50%	50%

*Units of all the parameter are in mg/l except EC (µS cm 1) and pH.

Total Dissolve Salts (TDS)

The amount of mineral and salt impurities in the water is called total dissolved solids (TDS). The electrical conductivity of water samples correlates with the total dissolved salts (TDS) of water samples. The range of TDS of analyzed water samples during pre monsoon period (figure 4. a) varied between 121 to 1556 mg/l. The post monsoon (figure 4. b) samples were found in the range of 509 to 1338 which is higher than pre monsoon. During pre monsoon, 62.2% of the samples were found above desirable limit while 53% of the samples were found above desirable limit during post- monsoon. During pre monsoon, the highest value (1556 mg/l) was observed at Near church, Ambala city while during post monsoon the highest value (1338mg/l) was observed at New grain market, Ambala Cantonment.

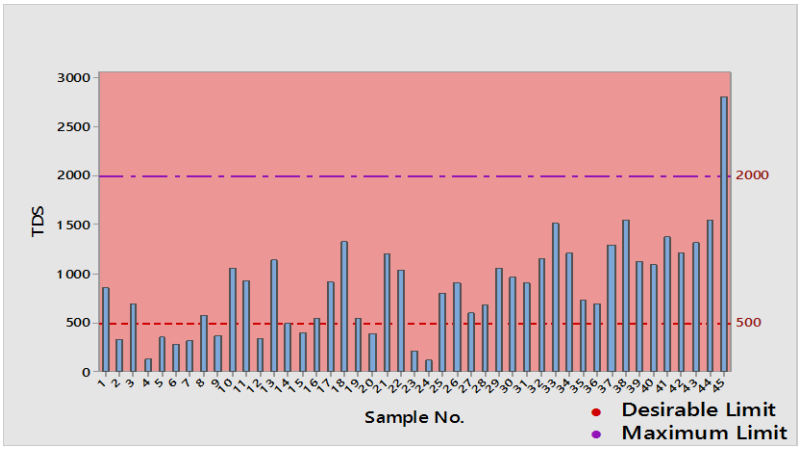

Figure 4: (a) Distribution of TDS (Pre- monsoon)

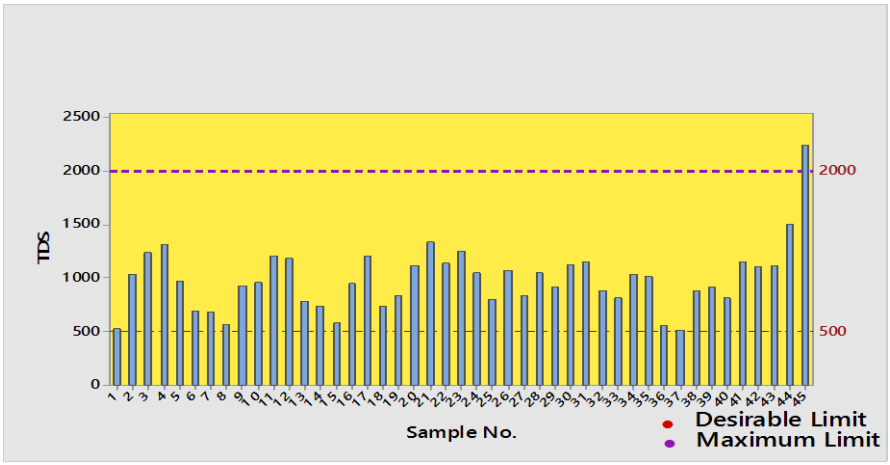

Figure 4: (b) Distribution of TDS (Post- monsoon)

Total Hardness (TH)

The acceptable limit of total hardness is 300-600 mg/l (BIS Standards). The hardness of analyzed water samples varied from 28 to 560 mg/l during pre monsoon period (figure 4.a). The analyzed water samples have been classified on the basis of hardness and results are presented in Table 2. Among post monsoon samples (figure 4.b), TH ranged from134 to 542 mg/l. During pre monsoon, the highest value (560 mg/l) was observed at Sector 8, Ambala city while during post monsoon the highest value (542 mg/l) was observed at Police lines Chowk, Ambala city.

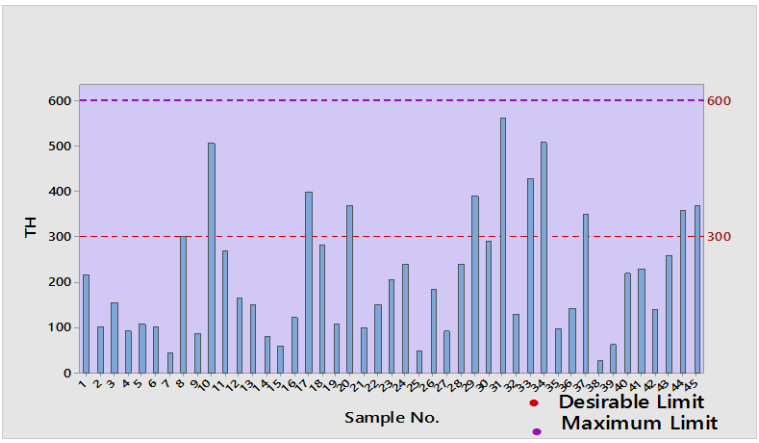

Figure 5: (a) Distribution of TH (Pre- monsoon)

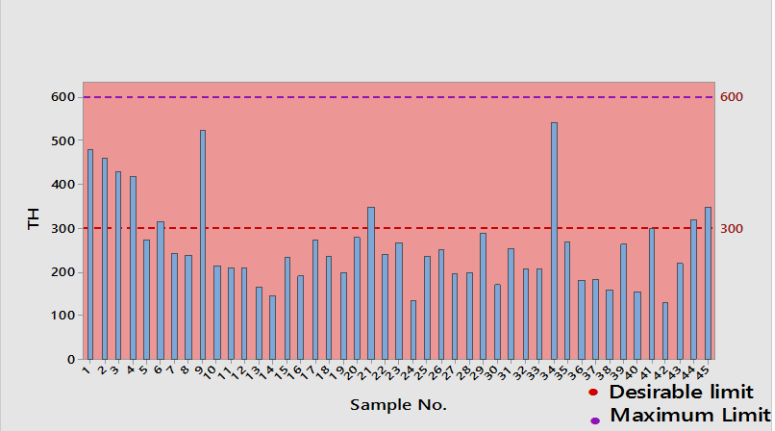

Figure 5: (b) Distribution of TH (Post- monsoon)

Table 2: Classification of water on the basis of total hardness

Total Hardness(mg/l)	Nature of water	%age of analyzed samples Pre- monsoon	%age of analyzed samples Post- monsoon
0-60	Soft	6.6%	Nil
61-120	Moderate	28.8%	Nil
121-180	Hard	17.7%	17.7%
>181	Very Hard	48.8%	82.2%

(After Durfor and Becker, 1964)

Calcium (Ca^{2+}) and Magnesium (Mg^{2+})

According to BIS and WHO, the acceptable limits of Ca^{2+} and Mg^{2+} are 75 mg/l and 30 mg/l respectively. The estimated Ca^{2+} content from collected water samples ranged from 4.2 to 227.1 mg/l and Mg^{2+} concentration ranged from 1.7 to 129.7 mg/l as shown in Table 1. During post monsoon season the range of values from minimum to maximum was 7.6 to 388 for Ca^{2+}, (figure 5. b) which is higher than pre monsoon (figure 5. a). Post monsoon value for Mg^{2+} varied from nil to 114.9. Both, during pre monsoon period and post monsoon 46.6 % of the samples of Ca^{2+} were found above desirable limit. For Mg^{2+} during pre and post monsoon 53.3% and 57.7% of the samples were found above desirable limit respectively. The reason for this variation may be the recharging of groundwater due to rainfall during monsoon period might have dissolved the calcium carbonate. During pre monsoon, the highest value of Ca^{2+} (227.1mg/l) was observed at Babyal, Ambala cantonment, while during post monsoon the highest value (388mg/l) was observed at District court, Ambala city. During pre monsoon (figure 7.a.)., the highest value of Mg^{2+} (129.7 mg/l) was observed at Sector- 8, Ambala city) while during post monsoon(figure 7.b.), the highest value (114.9mg/l) was observed at Babyal, Ambala cantonment.

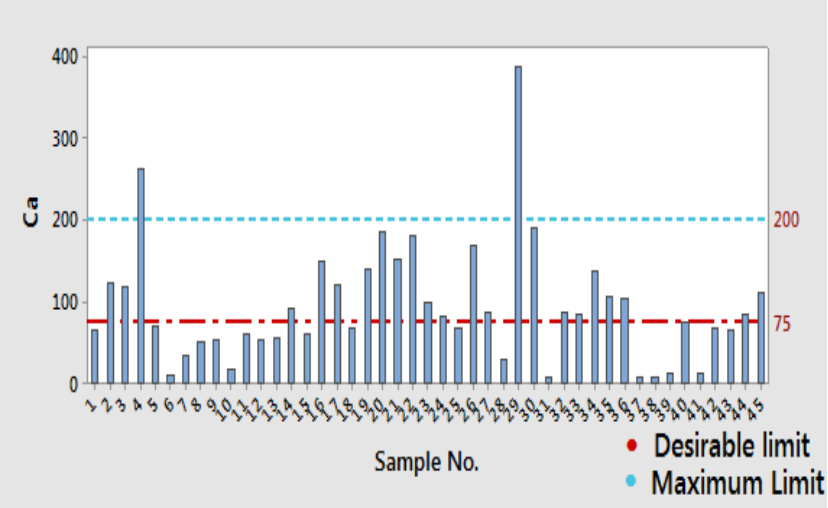

Figure 6: (a) Distribution of Ca^{2+} (Pre- monsoon)

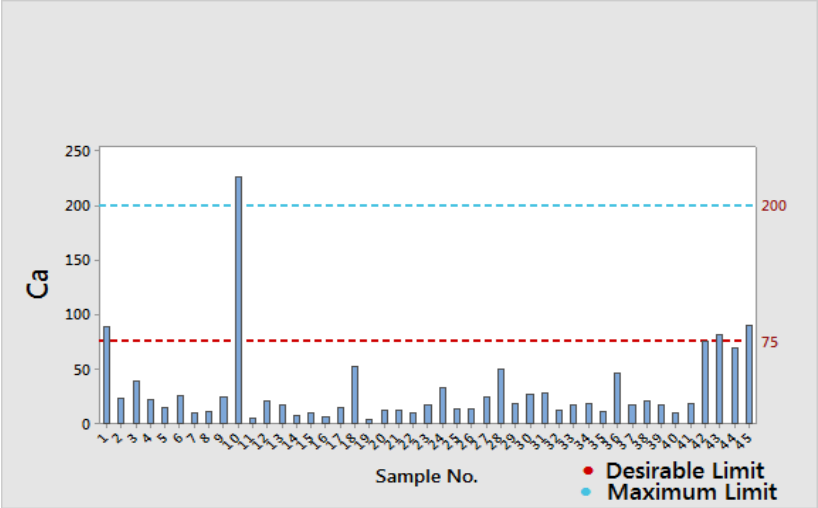

Figure 6: (b) Distribution of Ca^{2+} (Post- monsoon)

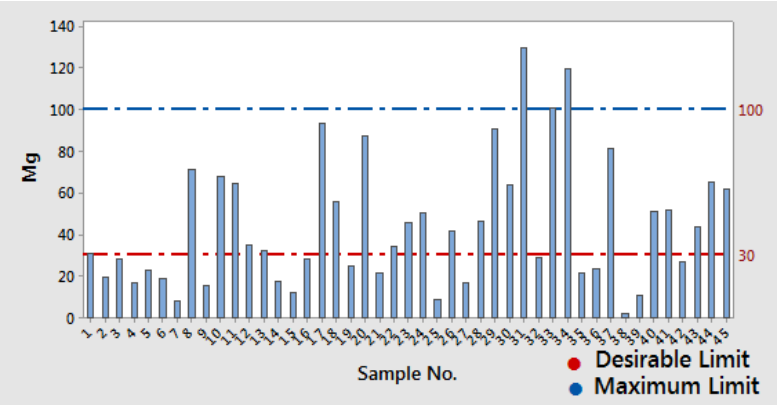

Figure 7: (a) Distribution of Mg^{2+} (Pre- monsoon)

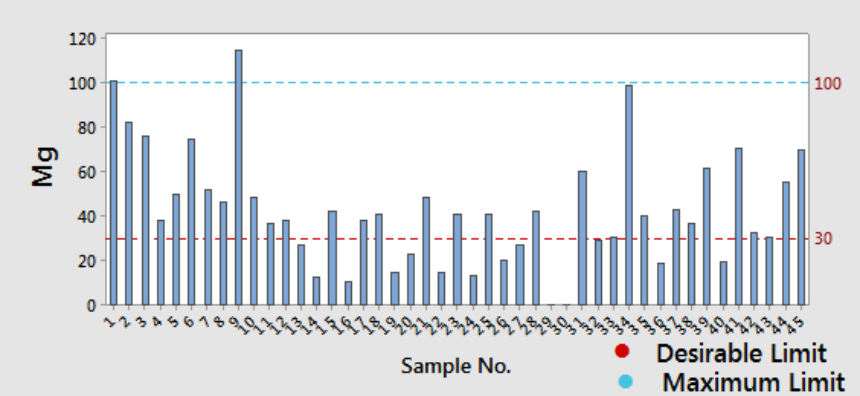

Figure 7: (b) Distribution of Mg^{2+} (Post- monsoon)

Sodium (Na^+) and Potassium (K^+)

During pre monsoon (figure 3.m), the range of Na^+ ions in water samples varied from 3.4 to 245.49 mg/l. During post monsoon season (figure 8.a), values for Na^+ lie between 83.7 to 396.9 which is higher than pre monsoon period. During pre monsoon, the highest value of Na^+ (245.49mg/l) was observed at near church, Ambala city while during post monsoon the highest value (396.9mg/l) was observed at New grain market, Ambala cantonment

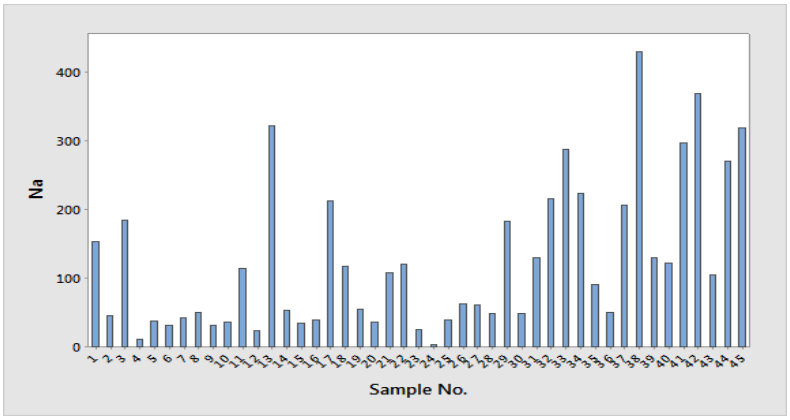

Figure 8: (a) Distribution of Na^+ (Pre- monsoon)

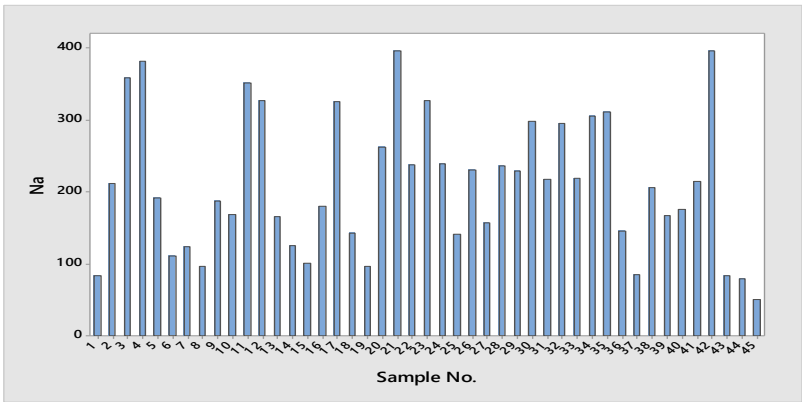

Figure 8: (b) Distribution of Na^+ (Post- monsoon)

K^+ is an important element for the living beings on the earth During pre monsoon (figure 9.a.), the range of K^+ ions in water samples varied from 0.8 to 10.8 mg/l. During post monsoon season (figure 9.b.), values for K^+ lie between 0.4 to18.7. During pre monsoon and the post monsoon, the highest value of K^+ was observed at Cloth market, Ambala city

(10.8mg/l and18.7mg/l respectively).

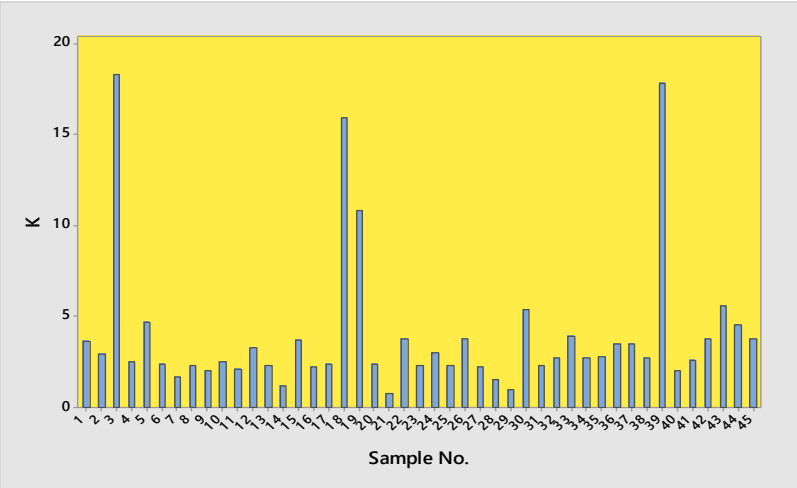

Figure 9: (a) Distribution of K^+ (Pre- monsoon)

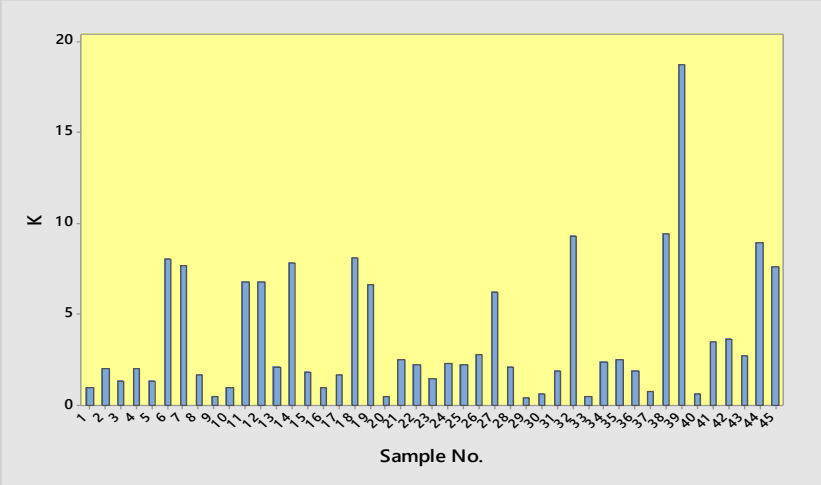

Figure 9: (b) Distribution of K^+ (Post- monsoon)

Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-)

The carbonate content of analyzed water samples varied from nil to 175 for pre monsoon (figure 10.a.) and the range was found nil during post monsoon (figure 10.b.). HCO_3^- content varied from nil to 1000 mg/l during pre monsoon and 35 to 335 mg/l during post monsoon as shown in Table 1. During pre monsoon the highest value of CO_3^{2-} was observed at Indira Park, Ambala cantonment. During pre monsoon, the highest value of HCO_3^- (1000 mg/l)was observed at Near church, Ambala city while during post monsoon the highest value of HCO_3^- (335 mg/l) was observed at Cloth market, Ambala city. All of the samples for CO_3^{2-} were found within permissible limit during both the seasons while for HCO_3^- all of the samples were found above the desirable limit. High value of bicarbonate might be due to carbonate from the underground rocks.

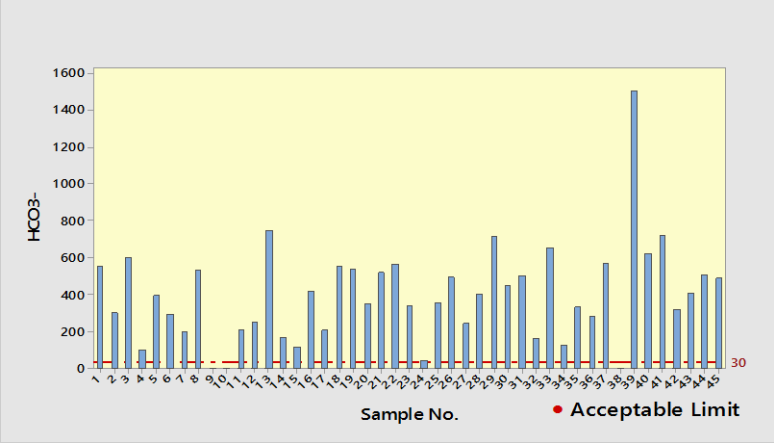

Figure10: (a) Distribution of HCO_3^- (Pre- monsoon)

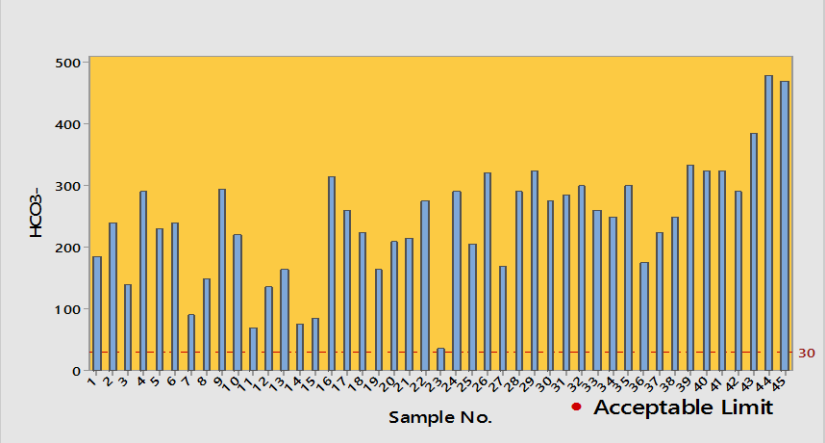

Figure 10: (b) Distribution of HCO_3^- (Post- monsoon)

Chloride (Cl^-)

In the analyzed water samples, during pre monsoon, the concentration of chloride varied from 21.3 to 582.2 mg/l while during post monsoon it was found between 49-788 mg/l. In comparison with BIS standard it was found that all samples showed concentration within the permissible limit. During pre monsoon 26% of the samples were found above desirable limit. During post monsoon 44.4% of the samples were found above desirable limit prescribed by BIS. All the samples of both pre and post monsoon season were also found below maximum limit of 1000 mg/l prescribed by BIS. During pre monsoon, the highest value (582.2 mg/l) was observed at Cloth market, Ambala city, while during post monsoon the highest value (788 mg/l) was observed at Subhash Nagar, Ambala cantonment.

Sulphate (SO_4^{2-})

The sulphate content in analyzed water samples varied from 107 to 284 mg/l during pre monsoon while during post monsoon, the value varied from 100 to 300 mg/l as shown in Table 1. All the pre and post monsoon samples were found to be below the desirable limit. During pre monsoon, the highest value was observed at police lines, Ambala city (284 mg/l), while during post monsoon the highest value was observed at Indira Park, Ambala cantonment (300 mg/l).

Nitrate (NO_3^-)

Nitrate is found in very less quantity in the groundwater. It enters in the groundwater due to excessive use of fertilizers, poor drainage system and change in land use. The range of nitrate was found between 1-11.6mg/l during pre monsoon. In post monsoon the value was found from nil to 6.3mg/l. The acceptable limit of nitrate is 45 mg/l according to WHO. Increased quantity of nitrates in infants causes methaemoglobiaemia. All of the samples were found below the desirable limit. Both, during pre monsoon and post monsoon the highest value was observed at Guru Nanak marg (11.6 mg/l and 6.3mg/l respectively).

Phosphate (PO_4^{3-})

The value of phosphate in the analyzed groundwater samples was observed between 0 to 0.7 mg/l. The phosphate concentrations of all the analyzed groundwater samples do not pose any water quality problem. During pre monsoon, the highest value was observed at Mahesh Nagar, Ambala cantonment (0.7 mg/l) while during post monsoon the highest value was observed at New Grain Market, Ambala Cantonment (0.7 mg/l).

Fluoride (F^-)

All of the samples were found below desirable limit during pre monsoon as well as post- monsoon. During pre monsoon, the highest value (0.65 mg/l) was observed at Supply depot while during post monsoon the highest value (0.48 mg/l) was observed Manav Chowk.

Total Alkalinity: The alkalinity value of the samples was found to be 62- 728 mg/l during pre- monsoon and 76-918 mg/l during post- monsoon. Both, during pre monsoon and post monsoon the highest value was observed at Police Lines (728 mg/l and 918 mg/l respectively).

Correlation Analysis: It is a bivariate method which exhibits the relationship between various elements. EC and TDS showed positive correlation with each other during pre and post monsoon periods. It was observed that both EC and TDS exhibited a strong positive correlation with Na^+ & Cl^-. Na^+ exhibited strong positive correlation with Cl^- (**0.76**) in the pre monsoon period which indicated geogenic sources. While during post monsoon period following parameters showed positive correlation:

EC is strongly correlated with TDS (**0.95)** which may be due to solubility and mobility of Cl^- , F^- and PO_4^{3-} in the groundwater. The correlation of EC with PO_4^{3-} indicates anthropogenic impact due to recharge of aquifers during monsoon period. While pH is positively correlated with F (0.51) and HCO_3^- (0.58) which depicts the alkaline nature of water and hence positive correlation of TH with Mg causing temporary hardness. This indicates the both anthropogenic as well as geogenic factors.

Table 3: Correlation Matrix of Chemical Constituents of Groundwater in Ambala city and Ambala Cantonment: Pre-monsoon

	pH	*EC*	*TDS*	*TH*	*Ca*	*Mg*	*Na*	*K*	*Cl-*	*F-*	*HCO3-*	*PO4-*	*NO3*	*SO4-*
pH	1													
EC	0.006	1												
TDS	-0.043	**0.9137**	1											
TH	-0.308	0.3375	0.3976	1										
Ca	0.068	0.2453	0.3142	0.3872	1									
Mg	-0.373	0.2916	0.3221	0.9607	0.1234	1								
Na	0.177	**0.8305**	**0.7707**	0.2255	0.09	0.223	1							
K	-0.038	0.0424	0.1216	-0.072	-0.006	-0.087	0.014	1						
Cl-	0.228	**0.8926**	**0.87**	0.3629	0.3709	0.265	**0.761**	0.019	1					
F-	-0.169	-0.149	-0.04	0.1005	0.2058	0.045	-0.253	0.0415	-0.1113	1				
HCO3	-0.354	0.2762	0.3365	0.0574	-0.151	0.102	0.229	0.2119	0.1591	-0.07	1			
PO4-	0.107	0.1911	0.3184	0.0874	0.1695	0.025	0.161	0.0537	0.1512	0.366	-0.11	1		
NO3	-0.148	0.2758	0.2706	0.2028	0.4762	0.078	0.111	0.4951	0.2773	-0.08	0.024	0.0257	1	
SO4-	-0.14	0.1632	0.1275	0.0822	-0.278	0.172	0.155	0.0131	0.1899	-0.32	0.169	-0.5009	-0.0365	1

Table 4: Correlation matrix of Chemical Constituents of Groundwater in Ambala city and Ambala Cantonment: Post- monsoon

	pH	*EC*	*TDS*	*TH*	*Ca*	*Mg*	*Na*	*K*	*Cl-*	*F-*	*HCO3-*	*PO4-*	*NO3*	*SO4-*
pH	1													
EC	0.25933	1												
TDS	0.27761	**0.951**	1											
TH	0.20477	0.154	0.24	1										
Ca	-0.1017	0.225	0.251	0.21	1									
Mg	0.30254	0.045	0.0957	**0.80**	-0.392	1								
Na	-0.4389	0.409	0.3373	0.11	0.34	-0.09	1							
K	0.38659	0.049	0.0802	-0.143	-0.321	0.07	-0.19	1						
Cl-	0.10058	**0.506**	**0.5816**	0.293	0.073	0.226	0.17	0.04	1					
F-	**0.50735**	**0.559**	**0.5096**	0.038	0.09	0.008	0.08	0.16	0.154	1				
HCO3	**0.57603**	0.491	0.4808	0.129	0.154	0.055	-0.12	0.09	0.222	0.43	1			
PO4-	0.30061	**0.507**	0.4724	0.17	0.066	0.146	0	0.04	0.178	0.41	0.34	1		
NO3	0.25309	0.458	0.374	-0.074	0.002	-0.07	0.13	0.13	0.026	0.35	0.16	0.34	1	
SO4-	-0.5273	0.27	0.3142	0.232	0.411	-0.06	0.73	-0.23	0.252	-0.1	-0.27	-0.1	0.048	1

Hydrochemical Facies of Groundwater

Piper diagrams (Figure 11 and Figure 12) for both pre and post monsoon season were created for the study area using the analytical data obtained from the hydrochemical analysis. In piper diagram the sample points can be divided into 6 fields i.e. 1. Ca-HCO_3^- type 2. Na-Cl type 3. Ca-Mg-Cl type 4.Ca-Na-HCO_3^- type 5. Ca-Cl type 6. Na- HCO_3^- type. In the present study it was found that during pre monsoon mixed $NaHCO_3^-$ and NaCl type of water dominated while during post monsoon mixed CaMgCl type of water dominated. The CaMgCl water types of post-monsoon are the byproduct of base-exchange process as Ca is being replaced by Na giving rise to NaCl and mixed CaMgCl type water in pre-monsoon samples. As the study area has alluvium aquifer and water from alluvial aquifer belongs to hard calcium bicarbonate or calcium magnesium bicarbonate type. Na was seen as major cation during both pre and post monsoon season. While during pre monsoon bicarbonate and chloride were dominating anions, Chloride alone dominated post- monsoon water. High value of sodium and chloride in water might be due to human activities and leaching process during monsoon season.

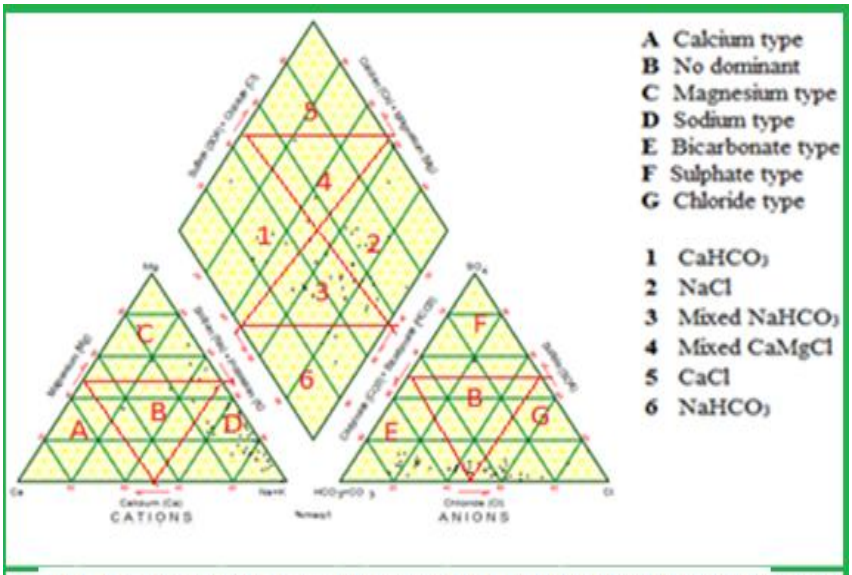

Fig.11. Pre- monsoon groundwater samples plotted in Piper- Trilinear diagram

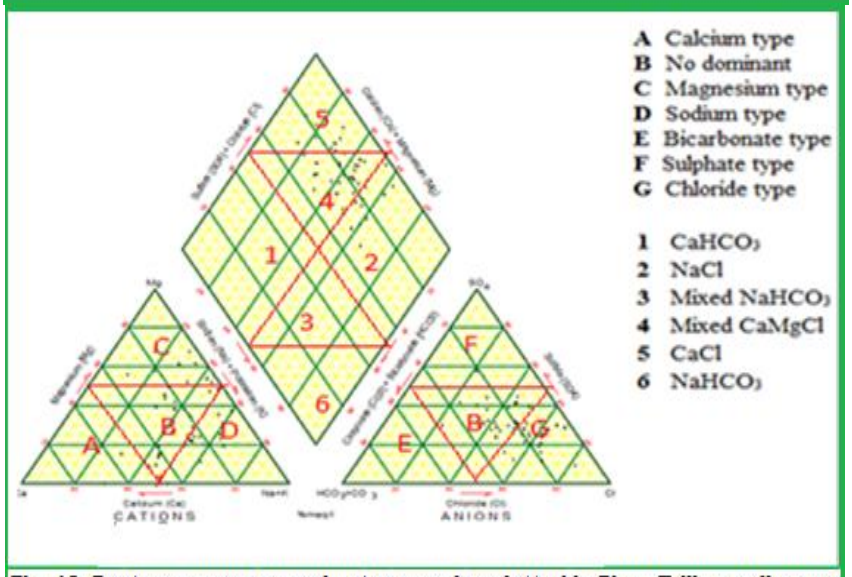

Fig .12. Post- monsoon groundwater samples plotted in Piper Trilinear diagram

Temporal variation in the physico-chemical parameters has been observed in the study area. The diluting effect of monsoon can be observed on pH as post- monsoon samples showed the lower values in comparison to pre- monsoon. The present study shows that during pre- monsoon season ground water in Ambala city and Ambala cantonment area is neutral to alkaline in nature. Higher value of TDS, sodium, chloride during post monsoon could be due to the dissolution of salts during monsoon season. High EC value in the analyzed samples shows the saline nature of water which may be attributed to the urbanization. High value of sodium in an urban area could be due to anthropogenic activities such as road salt, effluent from industries, septic systems and leachate from municipal landfills. For high sodium content, there could be some natural sources also, such as constant contact of groundwater with the rocks. The phosphate, nitrate and sulphate were found within the permissible limit. In groundwater the most common source of calcium and magnesium is through the erosion of rocks, such as limestone and dolomite and minerals, such as calcite and magnesite.

CONCLUSIONS

Apart from EC, TDS, TH, Na^{+}, Ca^{2+} and Mg^{2+}, all other physico-chemical parameters analyzed in the sampled ground water of the study area are well within the permissible limits set by the BIS: 10500:2012. It may be concluded from the present study that water quality of the study area is by and large fit for domestic and drinking purposes but needs treatment to minimize the contamination especially due to alkalinity and hardness. Thus it is suggested to monitor and assess the groundwater quality periodically in the study area for better management strategies.

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